The Development of Bio-Fuels in Brazil: Implications for Cottonseed**.**

Discipline: Agronomy & Soils

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Abbreviations/Acronyms:

Embrapa: The Brazilian Agricultural Research Corporation

TPE: tons of petroleum equivalent

Abstract: The world energy demand is expected to rise 1.7% per annum from 2000 to 2030, when consumption will have attained 18.3 billion tpe. Present petroleum geopolitical situation, the finite nature of oil reserves and the growing environmental concerns over fossil fuels clearly indicate the need for renewable and more environmentally friend alternatives. As an oil importing country, Brazil took a bold decision in the 1970's to find alternatives to fossil fuel creating its Proalcool (Ethanol Program). Today, the Brazilian ethanol chain is recognized as the most efficient in the world with a present annual output of 18 billion liters. With plenty of available land for agriculture, favorable weather, advanced tropical agriculture technology and a robust agro-industry, Brazil is poised to become a world leader in energy agriculture and an important player in the international bio-fuel market. Bio-diesel, from an array of oil producing plants, including cotton, will become an important component of the Brazilian energy matrix. By 2008, all diesel oil sold to final consumers must be at least 2% (B2) bio-diesel and increased to 5% (B5) by 2013. Cotton is a very important source of edible oil in Brazil, only second to soybeans. Presently grown cotton varieties have around 15% of oil in the seeds but research is underway to double oil output. If present cotton producing problems in the cerrados are solved and if the vast semi-arid zones rehabilitate their cotton production, bio-diesel from cottonseed might become a viable alternative with many economic and social benefits.

Keywords: bio-fuels, ethanol, bio-diesel, cottonseed, transesterification.

Introduction: The world energy demand is expected to rise 1.7% per annum from 2000 to 2030, when consumption will have attained 15.3 billion tpe (Gazzoni, 2007). With the success of its ethanol program and with plenty of available land for agriculture, favorable weather, advanced tropical agriculture technology and a robust agro-industry, Brazil is poised to become a world leader in energy agriculture and an important player in the international bio-fuel market. Bio-diesel, from an array of oil producing plants, including cotton, will become an important component of the Brazilian energy matrix. Brazil is a traditional cotton producing and exporting country. Presently, over 90% of the production comes from its savannah-like biome called cerrados located in its central region. The 2006-07 crop covered an area of 1.1 million ha and a production of over 1, 4 million t of lint is expected (Freire, 2007). This is quite a departure from the cotton scenario of only 20 years ago when more than 3 million ha were grown, especially in the Northeast region, for the production of less than 1 million t of lint. The introduction of the boll weevil in 1983 and the prevailing socio-economics of the cotton sector were responsible for this change in the Brazilian cotton geography, with much economic and social impact more deeply felt in the small holder agriculture of the Northeast (Barbosa et al., 1986). Cotton moved to the cerrados of Central Brazil as an alternative rotational crop to soybeans, becoming a rather advantageous economic option. It became a large operation, high input, fully mechanized activity enjoying high yields of up to 6t of seed cotton per ha, under rain fed conditions (Freire et al. 1999). In the mean time, Brazil became a world energy power for the success of its sugar cane- based ethanol program. Cotton may now face competition with sugar- cane for the good agricultural lands of the cerrados but may also benefit from the bio-diesel program if cottonseed becomes an economically viable option for bio-diesel production in comparison to other raw materials. This paper attempts to briefly describe the success of the Brazilian Agroenergy Plan, to introduce present cotton scenario in the Country and to explore perspectives for cottonseed in bio-diesel production, should some much needed technological and structural changes take place.

Cotton Growing in Brazil: From colonial times Brazil grows cotton, thereby generating jobs, income and wealth in rural and urban areas. Due to its semi-arid condition, the Northeast region became the traditional home of Brazilian cotton with plantations established there since the beginning of the Nineteenth Century (Martins, 1993). According to the same author, from the 1950's the prevailing cotton/basic food crops/livestock production system experienced a remarkable growth. In 1975, Brazil grew some 4 million ha of cotton, 78% of that area in the Northeast of which most were planted to perennial cotton (*Gossypium hirsutum var. marie-galante*). With plenty of cotton lint available locally, a very strong textile industry (second only to Sao Paulo) was established in the Northeastern states of Ceará, Pernambuco, Paraíba and Rio Grande do Norte and, in 1989, there were 5,699 cotton-related industries in full operation and generating more than 1 million jobs (Freire, 2001). Down South, other important cotton producing states at that time were Paraná, Sao Paulo, Minas Gerais and Goiás. The arrival of the cotton boll weevil (*Anthomus grandis* Boheman) in 1983 (Barbosa et al. 1986), coupled with socio-economic factors, brought a very serious crisis to the Brazilian cotton sector. From a large producer and net exporter, Brazil became the second largest world importer of cotton lint in 1993, when some 500,000t were imported. In 1997, the Brazilian cotton textile sector experienced a loss of US$ 1 billion, not to mention the loss of over 1.5 million direct jobs in rural and urban areas. Today, the traditional cotton producing semi-arid zones of the Northeast together with the states of Minas Gerais, Sao Paulo and Paraná are responsible for only around 10% of the Brazilian cotton. From 1998, a new cotton geography began to be drawn in the savannah-like biome of Central Brazil when rural entrepreneurs, the majority of Southern origin, adopt cotton in rotation with their soybeans, in areas where the boll weevil was not yet fully established. This new way of producing cotton with large, fully mechanized and high yielding operations left behind the traditional family farming based cotton production systems. The state of Mato Grosso, where more than 50% of the Brazilian cotton is now produced in farms of over 1,000ha and enjoying yields of up to 2 t of lint per ha, became the new home of the Brazilian cotton. With a steady growth of 25% per year, Brazilian cotton lint output went from 305,000 t in 1996/97 to 1,3 million t in 2003/04 (Freire et al. 1999 and Graham, 2006). However, the very impressive performance the Brazilian cotton sector has displayed recently faces many challenges that threaten its consolidation. These challenges are related to exchange rate that has fallen over the last years, to the ever increasing costs of production (presently estimated in US$ 1,750 per ha) and to the technological gap with other cotton producing countries for not having access to the most advanced genetically modified cultivars (Graham, 2006). Other very serious challenges are related to the fast movement of sugar-cane to the best lands of the cerrados and the quick colonization by the boll weevil now present in most of the area grown to cotton. If this pest - against which there is no GM cultivar available - is not taken seriously, it will eventually make cotton growing unsustainable throughout Brazil as it has already done to the Brazilian traditional cotton production zones and elsewhere in other Latin American countries and the US.

Ethanol Production in Brazil: Heavily dependent of imported oil at that time, Brazil reacted to the international petroleum crisis of 1973 by establishing its National Alcohol Program (PROALCOOL), created in 1975 by a Presidential Decree to meet the requirements of the domestic and international markets, as well as those of the fuel policy for automobile fuels. It gave incentives to produce ethanol from sugar-cane, cassava or any other raw material, with special emphasis on the expansion of agricultural production, the modernization and enhancement of existing distilleries and the establishment of new production units. The Brazilian ethanol production jumped from 555 million liters in 1975/76 to 17, 5 billion liters in 2007. Presently, approximately 14 billion liters of ethanol are consumed internally and 3.5 billion liters are exported. As a sole product (hydrous ethanol) or added to gasoline (anhydrous ethanol), ethanol fuel replaces 40% of the gasoline that would otherwise be used. In addition, from the 425 million t of sugar-cane produced by the 2006/07 crop, some 30 million t of sugar is being produced, of which two thirds are to be exported. The world sugar demand is increasing by 2% a year. In 2007, Brazil will export some 19, 5 million t of sugar, representing more than 45% of the free market in sugar, making Brazil the world's leader in sugar producing and exporting. With the number of Flex-Fuel vehicles in circulation in Brazil steadily increasing and the competitiveness of ethanol with gasoline at the present level (up to 40% cheaper at the pump), the sugar-cane crop is expected to surpass 700 million t in 2012/13, producing 36 billion liters of ethanol and 39 million t of sugar. This expansion is already taking place with new areas being dedicated to cane plantations, increased productivity in the agribusiness through R&D and the building of several dozen of new processing units. As long as the mean international oil prices are maintained above US$ 45 per barrel, ethanol produced from sugar-cane will be a very viable economic activity for Brazil, with many social and environmental spin-off benefits. Present day farming areas in Brazil only occupies 60 million ha or just 7% of its territory. Soybeans take 21 million ha, corn takes 12 million ha and sugar-cane, 5 million ha. There are estimations by Embrapa indicating some extra100 million ha can still be put to annual crops, away from the Amazon Rain Forest, the Atlantic Forest and the Pantanal (Castiglioni, 2004). Therefore, if appropriate legislation is set forth and enacted, Brazil will continue as the world leader in ethanol production from sugar-cane, without menacing its position as a food producing giant and without threatening its fragile ecosystems. Other raw materials - including wood, new crops and crop residues - and more advanced processes for ethanol production are being actively sought by a very aggressive national research program under the leadership of Embrapa Agroenergy. This research unit recently created within the structure of the National Agricultural Research System coordinated by Embrapa is one of the priorities of the Brazilian Agroenergy Plan - 2006-2011 of the Ministry of Agriculture, Livestock and Food Supply.

Bio-Diesel Production in Brazil: In 1895, Rudolph Diesel invented the diesel engine and presented it to the Paris World Fair in 1990, burning peanut oil. This was the birth of the bio-diesel. With the very cheap petroleum based diesel, the bio-diesel was almost forgotten until the oil crisis of 1973 (Fontana, 2007). In

1975, oleaginous plants were first considered for bio-diesel production in Brazil to replace petroleum derived diesel oil. A National Plan for the Production of Vegetable Oils for Energy Purposes (Pró-Óleo) was then established with the purpose of mixing 30% of vegetable oil to diesel oil, with the possibility of totally replacing diesel by vegetable oil. Later, in 2005, a more realistic National Program for Bio-Diesel Production and Use was created by law, definitely introducing bio-diesel in the Brazilian energy matrix and determining that the diesel sold to final consumers must be at least 2% (B2) bio-diesel by 2008 and 5% (B5) by 2013 (Beltrão, 2007). In order to meet program's 2008 goals, some 800 million liters of bio-diesel must be produced per year. Over the last 20 years, much progress in research has been made and many pilot plants were established throughout the Nation, producing bio-diesel from new and residual vegetable oils, animal fats and fatty acids obtained during the vegetable oil refining process. Bio-diesel is produced from oil or fat through esterification/transesterification, consisting of a chemical reaction of triglycerides with alcohols (either ethanol or methanol) in the presence of a catalyst (figure 1). By this process or, alternatively, through catalytic or thermal cracking, a mixture of chemicals is produced with properties very similar to petrodiesel. Owing to its condition of a tropical Country with continental dimensions, Brazil has many oil plants to chose from, native or introduced, to produce bio-diesel. Different regions will have their potential explored to benefit large rural populations from bio-diesel production. Therefore, not only traditional oleaginous crops such as soybeans, peanuts, cotton, sunflower, castor beans and African palm will produce raw materials for bio-diesel but, also, bubble bush(Jatropha curcas) and many native under-explored species like pequi or

Souari nut (*Caryocar brasiliensis*), buriti or aguaje palm (*Mauritia flexuosa*), macauba or grugu palm (Acronomia aculeate), babassu palm (*Orbygnia martiana*) etc. It will take much research before the potential of some of these plants may be fully realized. Table 1 lists crops readily available for bio-diesel production in Brazil. Either for the size of presently crop area and possibility for future expansion (soybeans), for their productivity (African palm, sunflower), or for their drought resistance (castor plant) some crops are receiving more attention for bio-diesel production in Brazil. Because of the above, soybeans produced in the Center-South is the most important supplier of raw material to meet the 2 and 5% goals. New and highly productive varieties of castor plants, producing up to 4 t/ha of castor beans, offer a very good possibility for family farming programs of the Federal Government in the poverty-stricken dry zones of the Northeast. On the other hand, the production of bio-diesel from African palm oil and from oil of some native palm trees of the Amazon may enhance important agro-forestry projects for the vast and under-populated Northern Region. As price of crude oil goes up and costs of producing bio-diesel tend to go down, with more productive crops and processes under development, the production of bio-diesel in Brazil is expected to become an economically viable alternative soon. With present costs of production, bio-diesel from soybeans becomes competitive when the cost of petroleum is situated at the level of US$ 65 per barrel (Gazzoni, 2007). The European Union is the world leader in bio-diesel production in spite of their very high cost of production. For Brazil to catch-up and meet its goals in bio-diesel production, the present plant derived oil output of 700kg/ha will have to increase to 5,000kg/ha in the next 20 years or so (Gazzoni, 2007).

Implications for Cottonseed: According to Chaudhry & Guitchounts (2003), ginned cottonseed contains in general 16% of crude oil, ranging from 15-22% in most cultivated varieties. Cultivated tetraploid species have more oil than cultivated diploids. There is a negative correlation between oil and protein contents. On the other hand, breeding for higher fiber content leads to smaller seed size, therefore, reducing oil content and vice-versa. Cottonseed oil has a high content of unsaturated fatty acids, especially oleic and linoleic, producing high quality bio-diesel at relatively low costs for being a by-product (or co-product). Comparatively, cottonseed derived bio-diesel produces less CO2 emissions than most of other plant derived bio-diesels and substantially less than petrodiesel, it does not produce S pollutants and is not corrosive. For its well-balanced contents of fatty acids and low acidity, cottonseed oil may be blended with castor and canola oil to meet the European Union specifications for bio-diesel. As result of continuous breeding for higher fiber content & quality, most of the presently grown cotton cultivars have small seeds, with a fiber output of over 40% and, consequently, reduced percentages of oil and protein. The challenge brought to Brazilian cotton breeders with present prospects for bio-diesel calls for the development of genotypes with 38-40% of good fiber quality and an increased oil content of over 25% from the present 14%. Due to the negative correlation, protein content will be reduced in favor of higher oil content (Beltrão, 2007). Embrapa is presently developing a cotton breeding project to achieve the above mentioned objectives. It will characterize 1,200 accessions of *G.* hirsutum of its germplasm bank in relation to oil content in the seeds. Within the first year of the project, it hopes to identify at least ten of these with oil content above 25%. With two breeding generations per year, 40 breeding lines with high oil and other superior fiber characteristics will be obtained by the third year of the project. At the end of the project, at least two new cultivars with high oil content (> 25%), superior fiber quality and resistant to the prevailing diseases will be released to the cotton growers of the cerrados and of the semi-arid zone of the Northeast. These new varieties will open the possibility for large cotton growers of the cerrados, singly or in cooperatives, to produce their own bio-diesel to fulfill their energy needs. Over 2,000 km away from the main Brazilian textile centers and from the coastal zone the hauling of cotton lint from the cerrados to industry or to the sea ports is done by trucks, greatly increasing costs. On the other hand, for the last few years the cost of fuel at farm level to produce cotton has more than doubled, now representing 8% of the overall cost of production. Farmers of the cerrados may decide to produce their own bio-diesel from cottonseed and other rotational oleaginous crops. The high oil cotton cultivars would also make possible the rehabilitation of cotton growing in the Northeast, the traditional land of the Brazilian cotton. This will create opportunities for the expansion of employment and income generation, with increased participation of small holders to benefit from government programs. Wherever bio-diesel from cottonseed becomes a reality in Brazil it can not become a panacea but should be seen as an important contribution to the diversification of the National energy matrix, together with other oil producing crops. However, in order for cotton to go back to the Northeast some basic limitations will have to be dealt with, including the presence of the cotton boll weevil which forced cotton displacement to the high cost and sophisticated production systems of the cerrados.

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Table 1 Characteristic of Oil Plants in Brazil

Plant Species	Oil origin	Oil content (%)	Harvest (Months/year)	Yield (t/ha of oil)
African palm	Nut	22.0	12	3.0 - 6.0
Coconut	Nut	55.0- 60.0	12	1.3 - 1.9
Babassu	Nut	66.0	12	0.1 - 0.3
Sunflower	Seed	38.0- 48.0	3	0.5 - 1.9
Canola	Seed	40.0- 48.0	3	0.5 - 0.9
Castor beans	Seed	45.0- 50.0	3	0.5 - 0.9
Peanuts	Seed	40.0- 43.0	3	0.6 - 0.8
Soybeans	Seed	18.0	3	0.2 - 0.4
Cotton	Seed	15.0	3	0.1 - 0.2

Adapted from Brazilian Agroenergy Plan 2006-2011.

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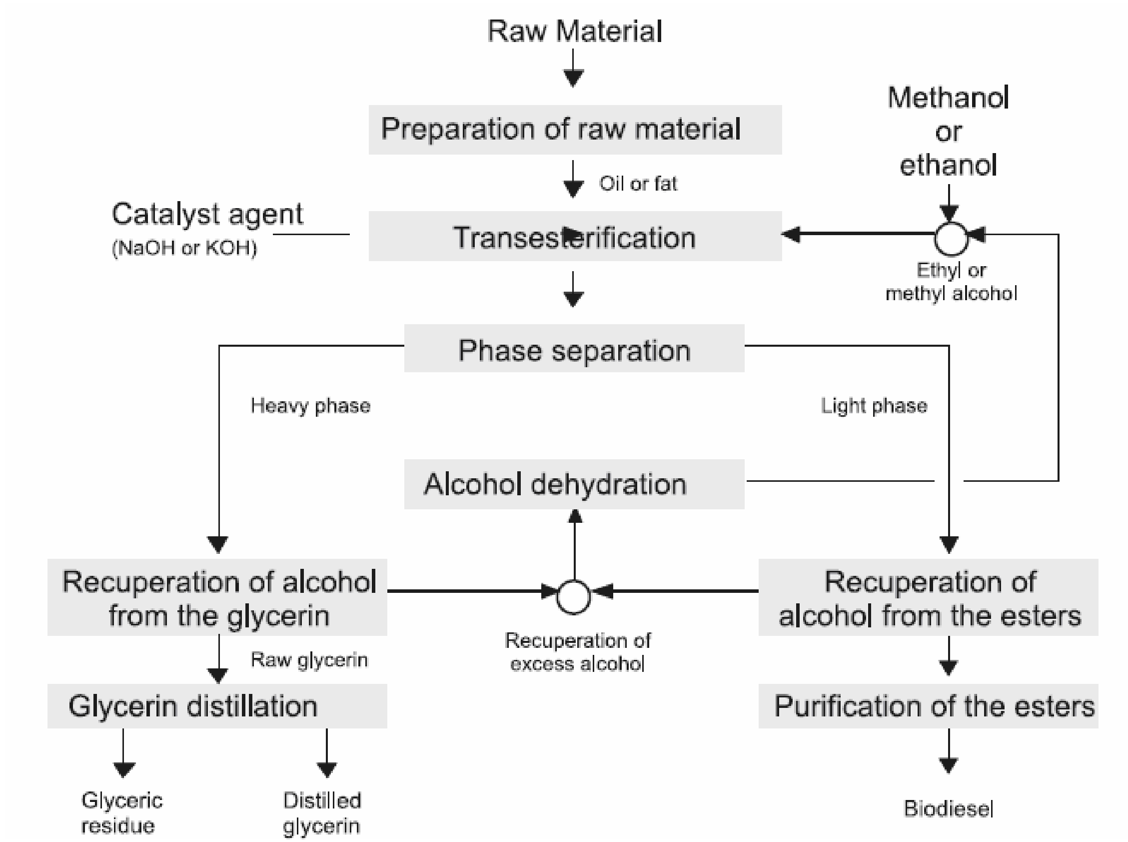
Figure 1. Bio-diesel production by transesterification

Figure1



(Brazilian Agroenergy Plan 2006-2011)